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by Westerners. This may be explained by the assumption that the ancestors of the Polynesians migrated from Southeastern Asia to the islands of the Pacific before cereals had replaced root crops as dominant plants.[13]

In Southeastern Asia we find both shifting and sedentary cultivators who depend exclusively upon root crops as a source of starch. The Nias, Mentawei, and Engano islanders off the western coast of Sumatra grew no grains until recently. Beside such root crops as taro (*Colocasia esculenta* Schott), yams (*Dioscorea* sp.), and *bira* (*Alocasia macrorhiza* (L.) Schott), they cultivated such other foods as bananas (*Musa sapientum* L.), sugar cane (*Saccharum officinarum* L.), and coconuts (*Cocos nucifera* L.). In the eastern parts of the Malay Archipelago and New Guinea the inhabitants depend chiefly on the starch of the sago palm (*Metroxylon sagu* Rottb.) which they either plant or collect in the wild state. Here, again, taro, yams, and bira are other sources of starch, as are such imported American plants as cassava (*Manihot utilissima* Pohl) and sweet potatoes (*Ipomoea batatas* Poir.). The folklore and religious practices of many tribes in Borneo and Celebes who today grow cereals recall the time when these tribes had only root crops.

In many parts of the Pacific taro is grown by sedentary cultivators on terraced, flooded fields.[14] We do not know whether the techniques of terracing and irrigation developed independently in Oceania and on the mainland, or whether the ancestors of the Polynesians brought their techniques with them from Southeastern Asia. If the latter be true, they must have left before the cultivation of rice was known to them; otherwise rice would have been among their crops. That it was not among them suggests that

[13] Forde: Habitat, Economy and Society, 1934, pp. 428–430. In remote centuries the Polynesians lived in the Malay Archipelago, where they cultivated such root crops as taro, yams, "arrowroot" (*Canna orientalis* Rosc.), and turmeric (*Curcuma* sp.), in addition to bananas and plantains (*Musa paradisiaca* L.), breadfruit (*Artocarpus communis* Forst.) and coconuts, all of which, according to the botanists, are natives of the forest regions of Southeastern Asia, whether the mainland or the Malayan Archipelago. All these plants were probably carried to Polynesia, either via a northern route through Micronesia or by a more southerly course through New Guinea and Melanesia. See Buck: Vikings of the Sunrise, 1938, pp. 305–309. The names of these plants were also carried into the islands of the Pacific. Variants of the names "taro" and "bira," to mention two examples, range from the Malay Archipelago far into Oceania. *Colocasia* is *talo* in Nias, *tales* in Sundanese, *tales* in Javanese, *dalo* in Fiji, *talo* in Samoan, *kalo* in Hawaiian, *taro* in Maori. *Alocasia* is known as *birah* or *bira* in Batak, *bira* in Madurese, *biga* in the Philippines, *piga* in Guam, and *via* in Fiji. Later, the Polynesians, following the example of other peoples of the Pacific, were quick to adopt such New World crops as cassava and sweet potatoes as well as American fruit trees into their economy because these are closely related to their customary crops, but they still remain most reluctant to change from roots to grains as staple, possibly because "the cultivation of roots and fruit trees has little technical relation to the raising of grains, for they are not grown from seed but from eyes and cuttings." See Forde: *op. cit.*, p. 380. Another illustration of the fact that a plant, the introduction of which involves a change in methods of cultivation, is accepted only under pressure, is found in the history of the introduction of the potato into Europe.

[14] Krämer: "Der Taro und die Nasskultur," 1928, pp. 165–172; Rivers: "Irrigation and the Cultivation of Taro," 1926, pp. 262–287.

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taro had been cultivated on permanent flooded fields earlier than had rice. Another possibility would be that taro, together with the technique of irrigation, was introduced into Oceania later than were the yams and alocasia, and the Polynesians' more important fruit trees.

A folktale of the Bontocs in the mountains of northern Luzon furnishes us with another clue. According to Bontoc lore, their hero, Lumauig, taught them agriculture in a tiny irrigated garden, which is still tended from generation to generation by a special priest. The crop of this garden is taro and not rice.[15] This would seem to lend support not only to the thesis that the cultivation of root crops preceded that of grain but also to the thesis that terracing and irrigation were already being practiced by cultivators of root crops.

A beautiful example of sedentary cultivation with root crops as a staple has recently been discovered in the remote Grand Valley of the Balim River in the highlands of Netherlands New Guinea. On the valley floor of the Balim and its tributaries neolithic people practice intensive cultivation, including such techniques as the use of green and animal manure, deep tillage with stone adzes, the digging of ditches to improve the run-off and drainage of swampy land, and the construction of terraces.[16] On the slopes they practice shifting cultivation. In both their shifting and their sedentary agriculture the staple crop is the sweet potato, while taro is a secondary crop. Also subsidiary are bananas, sugar cane, and pandanus.

In most parts of Southeastern Asia, however, root crops have been replaced by such cereals as millet, Job's tears, upland and lowland rice,[17] and maize. There seem to be good reasons to believe that the first cereals cultivated in Southeastern Asia under the system of shifting cultivation were foxtail, also known as Italian millet (*Setaria italica* Beauv.), and Job's tears (*Coix lacryma-jobi* L.). Before their domestication these grasses, like the root crops and fruit trees of Southeastern Asia, had been used by alithic and palaeolithic hunting and gathering people. Shifting cultivators succeeded in domesticating these plants by selecting over the course of years the species most valuable to them. Although foxtail and Job's tears have largely been replaced by the more valuable grains, rice and maize, there are still shifting cultivators in India, Thailand, Indochina, Malaya, the Indies, and the Philippines who raise the former cereals. Burkill says of foxtail,

> Such a crop as this probably came into cultivation before man had settled enough to grow the better cereals. Its grain ripens in even as little as two months and a half from sowing, and the wandering tribes of the Malay forests are able to remain in one neighbourhood long enough to catch a crop: but the usual duration of the crop seems to be four months.[18]

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15 Keesing and Keesing: Taming Philippine Headhunters, 1934, p. 56.

16 Brass: "Stone Age Agriculture in New Guinea," 1941, pp. 555–569.

17 Upland rice is also known as hill, mountain, dry-land, or dry, rice; lowland rice is also known as irrigated, wet-land, or wet, rice.

18 Burkill: *op. cit.*, Vol. 2, p. 1999.

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Probably the grain known as Job's tears was originally domesticated somewhere in the area between India and southern China, and it is still of importance in this area, although maize has competed with it since the latter's introduction into Southeastern Asia in the sixteenth century.[19]

Rice, The Basis of the Agricultural Economy of Southeastern Asia

By far the most important grain of both shifting and permanent cultivators in Southeastern Asia is rice, which occurs in the wild state in Africa as well as in various parts of southern Asia. The cultivated species (*Oryza sativa* L.) is probably descended principally from two Asiatic wild rices, *Oryza fatua* Koen. and *Oryza minuta* Presl. *Oryza fatua* is thought to be the dominant ancestral strain. These two ancestors are found in moist places from the Himalaya Mountains to Ceylon and from southern China through Indochina, Thailand, Burma, and Malaya to Java, Borneo, and the Philippines.[20] Rice was probably first domesticated in northeastern India, somewhere north of the Bay of Bengal, whence the domesticated varieties have spread in all directions: southeastward through Burma into the Malay-inhabited areas, eastward and northward into Farther India, China, Japan, Formosa, and the Philippines, and westward into the Near East and beyond.

The remarkably large number of distinct varieties of cultivated rice[21] has been interpreted as evidence of the great antiquity of its domestication. In the course of thousands of years of selection, varieties have been developed that are adapted to a wide range of natural conditions and especially to varying amounts of water. These varieties may be divided into two main classes: upland, or dry, rice and lowland, or wet, rice. The division, based on the two main types of agronomic practice, is not a very sharp one. Some upland varieties can be grown in flooded fields, and some lowland varieties can be grown in dry fields; however, it is said to be easier to grow dry rices in water than to grow wet rices on dry land.[22] In general, the areas suitable for the cultivation of upland rice are much more limited than those suitable for lowland rice, which can be grown outside the regions of assured rains, provided that water is available for irrigation; whereas upland rice must be grown in a humid atmosphere with an assured rainfall over a three- to four-month period.[23]

Upland rice is grown by the shifting cultivator, into whose economy it

[19] *Ibid.*, Vol. 1, pp. 629–631.

[20] *Ibid.*, Vol. 2, pp. 1593–1595.

[21] According to Copeland (Rice, 1924, p. 131) some 3500 varietal names are known in the Philippines; these may be presumed to describe more than 2000 different varieties; in India, where conditions seem to favor mass mutation, some 8000 varietal names have been recorded, but we do not know how many distinct varieties these represent.

[22] Burkill: *op. cit.*, Vol. 2, p. 1595.

[23] Lacking direct evidence, students of rice and its cultivation have frequently speculated on the comparative age of the two types. Some argue that the cultivation of wet rice preceded that of dry rice. They maintain that rice is, by nature, an aquatic plant. There are, however, grounds for thinking that the cultivation of dry rice is the older form. For one thing, there are wild varieties of upland rice.

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extensive open grasslands resulting from the most important tool of the shifting cultivator, fire. 241 134 311

Generally, the fallow period allows time only for the evolution of mediocre second-growth forest, for the shifting cultivator usually returns to an old ladang before even a small percentage of those tree species that made up the original stand have had a chance to come back. Repeated cultivations further impoverish the forest and reduce the number of species. Certain light-loving trees that played a minor role in the climax forest will spread rapidly and dominate, together with those species that show a resistance to fire and those that are capable of sending new sprouts out of the old stumps.[5]

If fire repeatedly invades an abandoned ladang, the tree flora is reduced until finally only grasses and herbs survive. These persist because their root systems, tubers, or bulbs send out new shoots after the fire. The more important grasses and herbs that finally triumph over forest vegetation are *Imperata cylindrica* Beauv., *Imperata constricta* Hitchc., *Saccharum spontaneum* L., *Themeda gigantea* Hack, and *Eupatorium odoratum* L. These burn very rapidly and with a hot flame, even when still green. After they are well established they catch fire or are set afire every year, almost without exception; this prevents natural reforestation. Furthermore, the fire will also invade the neighboring forest and force it gradually back, so that the grass area steadily increases. This is especially true in hilly or mountainous country. In the Philippines about 18 per cent of the total area is covered with grass vegetation as a result of shifting cultivation and fires. These grass areas are known locally as *cogonales*. In the Indies, where they are called *alang-alang*,[6] they are also extensive, as in southern Sumatra. While I was traveling through southern Sumatra by rail during the dry season I counted twenty grass fires started within the space of an hour by sparks from our locomotive. In Thailand there is as yet very little cogonal land, according to Pendleton.[7] In Indochina culturally induced grasslands, either pure or with scattered trees—the latter called by the French *forêts claires* or *savanes-parcs*—are very extensive[8] (Figs. 23, 24). [37] [23 24]

Once the vegetation of an area has been changed from forest to grass, the land is of no more agricultural use to the shifting cultivator. The only benefit that he then gets out of the land is for hunting. For this, too, he often utilizes fire—either to drive wild animals out of hiding or to get a growth of young grass to attract his prey.

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5 In Malaya and Sumatra the spread of such bushes and trees as *Lantana camara* L., *Schima bancana* Miq., *Peronema canescens* Jack, *Vitex pubescens* Vahl, *Melastoma malabathricum* L., and *Lagerstroemia speciosa* Pers. is due to the cutting of clearings.

6 *Imperata* (both *constricta* and *cylindrica*) is known in the Philippines by the Spanish term *cogon*, in the East Indies as *alang-alang*, and in Malaya as *lalang*. The last two are Malay words.

7 Pendleton: "Some Interrelations between Agriculture and Forestry," 1939, p. 41.

8 Gourou: L'utilisation du sol, 1940, pp. 368–372.

[See p. 38, cat. 241 or 116 -- Analyst]

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When fires no longer ravage the grasslands, however, trees return and finally drive out the grasses completely, for the latter cannot stand shade.[9] The spread of grass is especially rapid in regions with a long, pronounced dry season, whereas reforestation is more likely to take place in areas with a well distributed, high annual rainfall. This may explain why the Philippines and Indochina have a larger percentage of open grasslands than do Malaya and the Netherlands Indies.

A relatively high density of population is an important factor in preventing successful reforestation and encouraging grasses. In a thinly settled forest area there is sufficient land to allow for a long rest period, but an increasing density of population results in the shortening of the fallow period to such a degree that the soil is given insufficient time to recover its fertility. The shorter the fallow period the poorer the succeeding forest —if any—and the poorer the following crop yields, until finally the land can no longer satisfy the needs of the shifting cultivator.

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Pendleton believes that this cycle may have contributed materially to the downfall of the Khmers in Cambodia (Cambodge). He states that although the Khmers used the plow on very limited areas of wet riceland, they had largely to depend on the planting stick and shifting cultivation for their food supply. As the demands for more food arose from the rapidly increasing population concentrated in the city of Angkor, the fallow period granted to the uplands had to be progressively shortened. At the same time fires became so frequent that culturally induced grasslands spread while the cultivable area decreased, thus further diminishing the food supply available to the people of Angkor. "While the actual fall of Angkor is ascribed to the superior military power of invaders, the resistance of the inhabitants was doubtless much less than it would have been had the lands been productive and they had had adequate supplies of food."[10]

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Declining crop yields and the spread of grasses have been advanced as important reasons for the breakdown of the Mayan civilization,[11] and Pendleton further raises the question "whether the development of cogonals might not have been an important contributing factor in the dying out of some of the other civilizations of the tropics, notably that of Anuradapura, in Ceylon."[12]

Today the ruins of the Mayan cities, as well as those of Angkor, are surrounded by relatively luxuriant forest vegetation, which has had time to displace the pernicious grasses since man and his tool, fire, have abandoned the inhospitable grasslands.

Not only does shifting cultivation alter the character of the vegetation,

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[9] When an old ladang remains unburned for several years the following trees spring up in addition to those already mentioned in footnote 5: *Erechthites hieracifolia* Rafin., *Blumea balsamifera* DC., *Peltophorum dasyrachis* Kurz, *Macaranga tanarius* Muell. Arg., and *Piper aduncum* L.

[10] Pendleton: *op. cit.*, pp. 46 and 47.

[11] Cook: "Milpa Agriculture," 1921, pp. 307–326.

[12] Pendleton: *op. cit.*, p. 47.

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of shifting cultivation in the area. In such a case reforestation would be assured by keeping fire out of the old clearings. This could be done by leaving relatively non-inflammable forest belts at least 60 feet wide between individual clearings. These forest belts would offer some protection against the spread of grass fires and at the same time would be a source of seed for further reforestation. Reforestation under such circumstances would be much easier and cheaper than if large contiguous areas were to be cleared and used.

Where natural reforestation is particularly slow, cultivators should be required to practice artificial reforestation. In scattered regions in Southeastern Asia tribesmen do this on their own initiative. Pendleton reports such a case in Burma.[35] Certain Dyak tribes in Borneo plant seeds of the candlenut tree (*Aleurites moluccana* Willd.) about 3 meters apart in a freshly cleared ladang before it has even been burned. In the eastern part of the Malay Archipelago shifting cultivators plant such trees as *Aleurites moluccana* Willd., *Erythrina lithosperma* Miq., *Albizzia falcata* Backer, *Hibiscus similis* Bl., *Casuarina equisetifolia* L., *Macaranga* species, *Euphorbia* species, *Sesbania grandiflora* Pers., and *Desmodium timoriense* DC. for the purpose of restoring the forest.

In Sumatra Deli tobacco planters initiated artificial reforestation after alang-alang had regularly invaded their fallow fields and caught fire so frequently that second-growth forest could not get a start. In Deli the tobacco fields are in use only 1 year and lie fallow 7 to 10 years. They should be protected by forest growth during that period. Therefore, in order to make this possible, the planters controlled fires by planting belts of teak along the highways and roads. These belts served as fireguards and at the same time provided lumber for tobacco-drying sheds. On the tobacco fields themselves they planted especially *Albizzia falcata* Backer, *Cassia siamea* Lam., *Pithecellobium saman* Benth., and *Leucaena glauca* Benth., which drive out the alang-alang[36] (Figs. 34–39).

Another way of speeding up reforestation is to spare a few of the larger trees at the time of the clearing. This is done by the Malays of Sumatra. They do not cut down *Koompassia parvifolia* Prain, *Arenga saccharifera* Labill., *Durio zibethinus* Murr. (durian), *Parkia* species, or *Garcinia grandifolia* Pierre.[37] The last three are fruit trees that are numerous in the forest, whereas the second is a palm whose flower stalk is tapped for its sugary sap and the first is preferred by bees as a hiving tree, which gives it its name, "bee-tree." This tree is preserved because the people want the honey. Worthington reports that in Africa "some tribes appear to realize the necessity of maintaining tree growth on their clearings and merely top the trees and lop the branches, so that the trees are enabled to

[35] Similar cases are known in the residency of Benkoelen in Sumatra, in central Celebes, and in Flores. See Haigreis: "Ladangbouw," 1930, p. 631.

[36] Jochems: "De begroeiing der tabakslanden," n.d., pp. 77–89.

[37] *Ibid.*, pp. 30–32.

[See p 40 ff, cat. 116 --Analyst]

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protected against abnormal erosion. Terracing would be the most effective method of checking soil erosion, but this requires a good deal of labor, which is scarce in areas of shifting cultivation.

The Forestry Service of the Indies started an interesting soil-erosion experiment near Tjiwidej in the mountains south of Bandoeng at an elevation of 1800 meters. Two adjacent parcels of forest land, lying on rather steep slopes, are drained separately—out of each parcel comes a little brook—and thus form separate drainage units. Both parcels were used by shifting cultivators who had cut and burned the forest. In one case the slope was left undisturbed; in the other the slope was terraced. At the foot of each slope catch basins were constructed to retain the sediment that was washed down by rain water and transported by the brooks. The amount of water that drains out of each unit was measured and the sediment weighed. The purpose of this experiment was to get quantitative measurements of the amount of erosion that is caused by shifting cultivation and to study the effect of terracing in reducing soil loss. During the first year both parcels lost very little soil, because the humus layer protected it; but in the second year the unterraced parcel lost 5.065 kg. of silt per square meter whereas the terraced parcel lost only one-half as much, or 2.524 kg.[42] (Figs. 42–45).1

Under the conditions that we have discussed so far, no radical change in the system of cultivation is required. If, however, the population increases to such an extent that there is no longer enough available land to allow for a sufficiently long rotation cycle, more drastic remedies are necessary.

Such a situation arose in parts of the Outer Islands and attracted the attention of government specialists. Legal experts familiar with Indonesian customary law, foresters, and agricultural advisers collaborated to seek a solution.[43] Realizing that shifting cultivators are usually reluctant to give up their traditional form of land use, the specialists approached the ladang problem by searching for means of reforesting ladangs quickly. Experiments were made with the planting of quick-growing leguminous and non-leguminous trees, bushes, and shrubs to shorten the fallow period, restore the humus, protect the soil against accelerated erosion, eliminate the grasses, and, in the case of leguminous species, improve the soil by adding nitrogen.[44] We have already seen, however, that artificial refor-

[42] I was able to visit the Tjiwidej experiment with Mr. L. Gonggrijp, under whose supervision the work was carried out. For a detailed report on the project see Gonggrijp: "Het erosie-onderzoek," 1941, pp. 200–220.

[43] H. J. Friedericy of the Department of the Interior and H. Vonk and E. J. Wind of the Department of Economic Affairs, for example, worked together on the problem of ladang culture in the residency of Palembang.

[44] Experimental plantings included, among others, *Erythrina lithosperma* Miq., a light-loving tree which is typical in Southeastern Asia of dry, rather open climax forests and of second-growth forests; *Hibiscus tiliaceus* L.; *Albizzia falcata* Backer, one of the fastest-growing trees of Southeastern Asia, used widely as a shade tree on coffee plantations; *Aleurites moluccana* Willd., a tree at home in the drier parts of the East Indies; *Leucaena glauca* Benth.; *Pterocarpus indicus* Willd., a large tree frequently used along roadsides as

1 [see p. 42, category 16 -- Analyst]

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estation is not a discovery of Western-trained scientists but has long been practiced by certain groups in Southeastern Asia. It was the plan of the government to spread and enforce this practice of artificial reforestation wherever advisable. This practice, whereby the cultivator determines the vegetative cover during the fallow period instead of abandoning the ladang to chance growth, brings him to a transition stage between shifting cultivation and permanent cultivation. From there the step to permanent cultivation with crop rotation is but a short one.

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Permanent cultivation requires repeated tilling and therefore more labor and tools than the shifting cultivator is accustomed to. Work animals are also desirable. An important obstacle to intensification of agriculture in wide areas of Southeastern Asia, however, is the fact that hill and mountain regions [up to about 1500 meters in elevation] are frequently infested with malaria so that the energy of the people is greatly reduced.[45] Moreover, the acquisition of such implements as plows, harrows, and hoes, and especially of work animals, calls for financial resources or credit, both of which the average shifting cultivator lacks. Some shifting cultivators do own livestock, such as cattle or carabaos, but utilize neither their labor nor their manure. Groups of the Mois in the mountains of Annam have carabaos, but they do not use the animals in their agricultural activities because they "cannot talk" to them.[46] On the Lesser Sunda Islands livestock is kept because it gives social prestige to the owner. Overstocking of the pasture areas on these islands has led to overgrazing and has cut into the forest area until there has developed a scarcity of land suitable for ladang cultivation. The same has happened in large areas in Africa. There it has been necessary to teach the native peasant the use of cattle and make him familiar with the plow. This was done successfully in northern Nigeria by combining the animal husbandry of the nomadic Fulani with the indigenous shifting cultivation of the Hausa peasant, thus developing "a system of permanent farming whereby a man with cattle of his own, say two working oxen and a few cows, can plough and maintain in fertility an area of land sufficient to supply all the requirements of himself and his family, and to obtain a surplus balance as a return for his labour. . . . Thus mixed farming represents a gradual evolution from the shifting methods of cultivation to a static type of agriculture, by the introduction of animal husbandry, and with the use of animal cultivation."[47] Above all, the peasant learns to preserve the animal manure and

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a shade tree; *Dolichos lablab* L., a climbing herb which is valuable as a vegetable; *Crotolaria anagyroides* H.B. and K., a bush of vigorous growth which attains a height of from 12 to 14 feet and forms an excellent green manure; *Tephrosia candida* DC. and *Tephrosia vogelii* Hook., low shrubs useful as green manures; and *Mimosa invisa* Mart., a leguminous creeper which suppresses grasses.

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45 Gourou: L'utilisation du sol, 1940, pp. 181 and 350.

46 *Ibid.*, p. 354.

47 King: "Mixed Farming in Northern Nigeria," 1939, p. 271. See also Faulkner and Mackie: West African Agriculture, 1933; and by the same authors: "The Introduction of Mixed Farming in Northern Nigeria," 1936, pp. 89–96.

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Chapter III

THE SEDENTARY CULTIVATOR

241 Sedentary, or permanent, cultivation of land is much more vital to the economy of the countries of Southeastern Asia than is shifting cultivation. The majority of peasant cultivators obtain their livelihood by tilling the same piece of land year after year. The continuously utilized arable land, however, is not all cultivated in the same way throughout Southeastern Asia. We may distinguish three main categories of arable land: garden land, surrounding the houses and villages; wet land; and dry land. These three classes of land are devoted to different crops and vary so much from one another in size and reliability of yields, and therefore in value that in Java, for example, the social status of a man depends upon the type of land that he cultivates. There are districts in Java where only those peasants who own wet land, houses, and garden land have the full rights of a villager.

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The Garden Plot

244 Garden culture on land surrounding peasant houses in Java is devoted to a large variety of crops, ranging from fruit trees to plants that are not required in large quantities but only to supplement the diet and add flavor to the daily rice meal. Ochse and Terra, who have made exhaustive studies of garden culture, are of the opinion that it is a remnant of "primitive grainless hoe culture," in which all the useful plants found in the forest were concentrated in plots near the dwellings. Originally, the number of plants grown in the garden was greater than it is today, for some plants have been taken out of this economy to be grown on a larger scale in fields. The origin of garden culture explains, according to Ochse and Terra, the truly amazing variety of plants that are found on garden land.[1] Sollewijn Gelpke, a leading expert on native agriculture in Java during the past century, remarked on the richness of the gardens:

> Whoever strolls around a compound and takes things in with a botanical eye will see before him a variety of plants of which the uninitiated can have no conception. . . . Such wealth of vegetation is still more impressive to him who approaches it from an economic point of view. He sees palms, bamboo, bananas, and other trees that resemble each other closely, bearing fruit and giving support to various climbing plants.[2]

244 137 Often one is able to distinguish three levels, or stories, in a garden. The ground story consists of low-growing plants, especially tuberous plants that tolerate shade, such as elephant yam (*Amorphophallus campanulatus* Bl.), white arrowroot (*Maranta arundinacea* L.), "purple arrowroot" (*Can-*

1 Ochse and Terra: "Het onderzoek," 1934. See also Terra: "De voeding der bevolking," 1932, pp. 552–593.

2 Sollewijn Gelpke: Naar aanleiding, 1901, p. 203.

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na edulis Ker), sweet potato (*Ipomoea batatas* Poir.), taro (*Colocasia esculenta* Schott), *Curcuma* species, Goa bean (*Psophocarpus tetragonolobus* DC.), bitter cucumber (*Momordica charantia* L.), snake gourd (*Trichosanthes anguina* L.), Lima bean (large) (*Phaseolus lunatus* L.), Goa potato (*Dioscorea aculeata* L.), wild yam (*Dioscorea hispida* Dennst.), and sweet yam (*Dioscorea alata* L.). The middle story contains taller-growing plants, such as cassava (*Manihot utilissima* Pohl), citrus varieties such as *Citrus nobilis* Lour. and *Citrus aurantifolia* Swingle, papaya (*Carica papaya* L.), banana (*Musa* species), rose apple (*Eugenia aquea* Burm.), and soursop (*Anona muricata* L.). The upper story is formed by tall fruit trees, such as coconut (*Cocos nucifera* L.), jackfruit (*Artocarpus integra* Merr.), sapodilla or chico (*Achras zapota* L.), pomelo (*Citrus maxima* Merr.), of which numerous forms, differing in size and color, are known in the Indies, *belinju* (*Gnetum gnemon* L.), mango (*Mangifera indica* L.), durian (*Durio zibethinus* Murr.), candlenut tree (*Aleurites moluccana* Willd.), tamarind (*Tamarindus indica* L.), *pete* (*Parkia speciosa* Hassk.), stinkbean tree (*Pithecellobium lobatum* Benth.), and *santol* (*Sandoricum koetjape* Merr.).

This list does not by any means include all the plants that appear in the gardens. The plants vary in number and type from region to region in accordance with differences in soil, climate (elevation), and the taste of the owners.

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Estimates indicate that about 15 per cent of the cultivated land in Java and Madura is taken up by gardens. Unfortunately, there have been no detailed studies of garden culture outside of Java, although the products of the garden play an important role in the diet of all the peoples of Southeastern Asia. Terra, who compared garden culture in various districts of Java, found that the share of land allotted to gardens, together with the intensity of their cultivation, increases as the total amount of crop land per head decreases, down to the point where the average amount of crop land per head is only 0.15 hectare. Where the amount of land is even less than this the share of garden land decreases, although there is a tendency at first to increase the intensity of the garden culture. Close to the larger cities, the amount of crop land per person, together with the amount devoted to gardens and the intensity of the latter's cultivation, falls off to a minimum since the population here has supplementary sources of income.

With the development of a money economy appears a specialization that is directed toward the urban centers. There has always been some natural specialization inasmuch as some plants do not grow well everywhere. The coconut, for example, does best in the lowlands. But the new specialization depends not only upon such natural factors as soil and climate, but also upon economic factors such as marketing facilities and the development of communications. This specialization can be observed generally in Southeastern Asia.

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Ochse and Terra found that in calories of food value the returns of the gardens proved to be slightly higher per hectare than those of the irri-

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gated fields. One of the great advantages of garden culture over field culture is that there is always something ready to harvest from the former and therefore something to sell when money for daily household needs becomes scarce. Another advantage is that the garden supplies the family with a great variety of side dishes rich in vitamins; the vegetable proteins of the garden produce are also of high value.

As to the possibilities of improving garden culture, these two authors state:

> It is very evident that an improvement of the compound horticulture is a very difficult problem through the highly varied and dense planting of these compounds as a result of which they come to resemble a very complicated symbiosis. But for all this it must be possible by systematic investigation to improve not only the quality but also the quantity of the production. It may be said that the compounds with their story or layer formation superficially considered will find no favour in the eyes of western agriculture, but they are an essential link in the native production apparatus.[3]

The alarming decline in the welfare of the people of Java in the face of a mounting population prompted Netherlands Indies officials to examine every possibility of improving the peasants' condition. This accounts for the studies of Ochse and Terra. Lacking detailed studies outside Java, we are obliged to depend upon scattered references of uneven value.

Credner states that in Thailand practically every house has a few trees on the lot, and the villages are often hidden by tree clusters. The greatest intensification of garden culture is found on the right bank of the Mae Nam Chao Phraya (the Menam) in Bangkok Noi, just opposite Bangkok. Here irrigation is employed in garden culture, a technique not usually found in Southeastern Asia. The gardens are surrounded by walls 1 meter high and are traversed by trenches 2 meters apart. The beds between the trenches are elevated. The trenches work both as drains and as irrigation ditches. Small sluices control the water. In the gardens there is a great variety of fruit trees and palms which climbers, such as *Piper betle* L., use as supports. In the trenches the peasants grow lotus and water chestnut (*Trapa natans* L.).[4] Zimmerman, in his survey of rural Thailand, points out that in most regions the peasants rely too much on one crop, rice, and he recommends in several instances improvements in the cultivation of the home lots so that families may have a better supply of fruits and, above all, of vegetables. In the Khlong Rangsit section he observed that "on account of the lack of homestead and village sites among the people there is no gardening and home production of food."[5] This observation may be applied to Southeastern Asia in general. Wherever the dominant form of land tenure is tenancy the flimsy shack of the tenant has no mixed fruit and vegetable garden around it, for his status is much too uncertain. A tenant

[3] Ochse and Terra: *op. cit.*, pp. 371–372.
[4] Credner: Siam, 1935, p. 246.
[5] Zimmerman: Siam, 1931, p. 307.

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rice takes up nitrogen in the form of ammonia, the value of green manures on wet-rice fields is apparent.[15] In the Indies, *Crotolaria* species are the most frequently used green manures, the favored one being *Crotolaria juncea* L.; but *Phaseolus lunatus* L., *Dolichos lablab* L., and *Pachyrrhizus erosus* Urban are also used. The peasants of the Red River delta in Tongking are in the habit of working into the ground the wilted matter of a number of legumes that have been grown primarily for seed. The peasants of the province of Nam Dinh have developed a technique that may be unique. They push handfuls of indigo branches into the ground between the rows of rice a few days after the latter has been transplanted, for they believe that indigo is superior to pig manure or human excreta. In Indochina rice-growers frequently cultivate green manure, especially *Crotolaria* species, on dry fields and carry it to the rice fields at the time when these fields are being prepared for the seedlings. A green manure used exclusively in a few districts of the delta land of Tongking is the small aquatic plant, *azolla*.[16] Certain villages, thanks to favorable circumstances, have specialized in the growing of azolla to sell to the surrounding country, while other villages reproduce the plant until sufficient quantities of green manure have been obtained to cover all needs. The life cycle of azolla is completed in the months from November to April or May. Only the villagers of LaVan know the secret of maintaining and multiplying the plant during the hot season. They guard this secret jealously since it is the basis of their livelihood.

Further studies are needed to establish which varieties of green-manure plants are best suited to the various environmental conditions. It is important to find plants that grow rapidly and can be sown when the rice is still on the field, just after the water has been drained off to allow the grain to ripen. Experiments should also be made in the timing of the application of green manure. Should it be early, or just before the transplanting of the seedlings? Should it be on dry or on wet land?

Crop rotation also has its place as a means of keeping up the fertility of wet-rice fields. This practice seems to be better developed and more prevalent in Java than in any other country of Southeastern Asia. Extensive areas of *sawah*, as the Javanese call their wet riceland, are planted with dry-field crops such as maize, legumes, and other vegetables during the dry season, a practice that has a beneficial effect upon the soil. This form of double cropping is probably better than raising two rice crops in one year, because—although a different variety of rice is chosen for each season—both make essentially the same demands upon the soil; whereas a peanut crop, for example, grown during the dry season will enlarge the nitrogen content of the soil. In some areas of Java lowland rice is rotated

[15] Imperial Bureau of Soil Science: Tropical Soils in Relation to Tropical Crops, 1936, p. 11.

[16] For a map showing the extent of the use of azolla, see Gourou: Les paysans, 1936, p. 392. For further discussion see Nguyên-cong-Tiêu: "L'azolle," 1930, B, pp. 335–350 (also in *Proc. Fourth Pacific Science Congress, Java, 1929*, Vol. 4, 1930, pp. 355–370).

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Chapter Four

SOUTHEAST ASIA'S NATURAL VEGETATION

Tropical Forest Factors

The heavy, evenly distributed rainfall and constant high temperatures of most of Southeast Asia encourage continuous plant growth and a profuse, very varied flora. Because the whole year is here a growing season, plant life becomes almost overpowering in its rate of growth. This region contains more species than any other; the flora is not yet completely known, but some 35,000 species of flowering plants alone are thought to exist there (van Steenis). On Borneo at least 11,000 species have been listed, according to Merrill. This contrasts with the parallel figure of 13,000 species for the whole of Tropical West Africa (Good). Woody plants predominate and 15 per cent of the species are trees whose mature trunks are over 16 in. in diameter. The profusion of species is due to (*a*) the predominantly warm, moist climate, (*b*) the constancy of this climate over long geological periods, (*c*) the variety of relief and islands producing minor adaptations, (*d*) the rapidity with which selective and adaptive evolutionary processes can establish new characteristics in a tropical climate which has no resting season, and (*e*) the migrations of plant types from both Asia and Australia.

Southeast Asia was originally clothed by nature almost entirely by a tree cover. Only in modern times has there been any extensive clearing because apart from firing, primitive people were technically incapable of removing the forest. Some clearings became permanent for cultivation, in recent centuries, but the majority have been temporary and partial clearings, later left to natural replacement by a selective vegetation such as grass, savannah or scrub. Temporary clearings resulted largely from systems of shifting cultivation which finally abandon an area, partially cleared by fire, to a series of quick-growing plants, becoming after a few years a secondary forest which may, over prolonged periods, evolve to be scarcely distinguishable from primary forest.

The system of migrant agriculture or shifting cultivation, in Malaya called *ladang* and in Burma *taungya*, is widespread through-

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out Southeast Asia and it may be this form of nomadism has in fact operated so long that it affects nearly every acre of the region, thereby exercising a distinct selective action on the whole forest (Sauer). Much forest which we call "primary" may be senile secondary. This is evident in more densely populated areas such as Java and Tonkin, and over the centuries may have no less influenced the forest types of even thinly populated zones, as Borneo still is. In this sense "primary forest" is a relative term, to be retained for convenience rather than as presupposing an absolutely virgin tropical forest.

Two main types of primary lowland forest may be distinguished, the critical factor being drought:

1. In those zones astride the Equator where no season may be called dry, the natural forest is a tall, leafy, congested and evergreen type known as Tropical Rain Forest, sometimes called Equatorial Rain Forest. It may even occur well away from the Equator, towards the northern limit of Southeast Asia, where certain local conditions create a more continuously wet climate than is normal for the latitude.
2. In localities where there are several consecutive months practically without rain, a shorter and more open forest type develops: it has deciduous foliage on the whole, and considerably fewer species. Deciduous Tropical Forest is more generally known as 'Monsoon Forest' and occurs over huge areas in eastern Java, Burma, Siam and Indochina.

Between these Tropical Rain Forests and Monsoon Forests, there are intermediate types and transitional areas where no single meteorological criterion can be used to define the boundary sharply. Within both types, local peculiarities of soil porosity, number of rain-days, relief, exposure and aspect all induce minor variations. In any given unit of this mountainous region, three zones of vegetation may be distinguished within both main forest types, these zones being more distinctive in their differences than the variations of vegetation from one part to another of this huge region. These zones are: (1) coastal vegetation, (2) lowland vegetation, (3) mountain vegetation.

(1) Coastal Vegetation

On shores predominantly sandy, short herbs, grasses and shrubs with creeping stems and fleshy leaves are found; these plant

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groups resemble those of salt-tolerant vegetation on European beaches of which spinifex is a sample. Behind this shore grows a distinctive strip of what may be called *beach woodland*, sometimes referred to as beach forest. On reefs, on muddy shores and estuaries, where there is diurnal flooding at high tide, the *mangrove* forest develops. When the shore is rocky, lowland forest may reach high tide mark. In this vegetation seeds and fruit are waterborne so that currents are an important means of dispersion.

Well-developed beach woodland forms as a ribbon rarely more than 200 ft. inland from the shore and contains tree types not usually seen elsewhere and often reaching 90 ft. in height. The typical tree, the casuarina (Equisetifolia, rhu, ru, tjemara) is rather like a conifer to look at and is related to Australian she-oaks. Sometimes the casuarina is in pure stands; at places the strip includes screw pines (Pandanus), the leathery-leaved Calophyllum, Inophyllum and Barringtonia. Coconut palms, which can take root after nuts have been dispersed by sea-currents, are now prominent in beach woodland areas as a planted crop, but they occur self-sown everywhere through the islands.

Mangrove forests are widely distributed on sedimenting shores throughout Southeast Asia. The fringe of mangroves is interrupted where rocks or cliffs come to the sea and when drainage control has diminished the silt from terrestrial sources. Where mangroves develop, silt is being deposited at a fast rate (sometimes to a thickness of 1½ in. annually); the mangrove thus both raises the surface level and progressively presses farther seaward. Whether mangroves grow only where silt is being deposited or whether they cause silt deposition by their root system, obstructing tidal currents and flood run-off, is still disputed. Possibly both processes operate together. The net effect is one of raising the land level and reclaiming land from the sea. In addition, the wood of mangroves is valued for firewood and charcoal; the bark is sold extensively for tanning. The mangrove trees are of some thirty species, all with structural adaptations enabling them to root in unstable muds and to tolerate daily inundation of their root system by saline tidal water. In addition to the tree, there are shrubs, herbaceous plants and ferns (particularly Aerostichum aureum). The trees are evergreen, sometimes 100 ft. tall, mostly with shining, leather-like leaves, small flowers, and unusual root systems. Some (as Rhizophora) have many roots supporting the trunk which begins well

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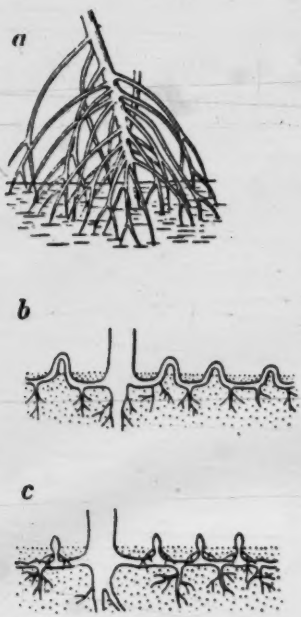

FIG. 22. — Mangrove Root Types. (*a*) The stilted roots of Rhizophora. (*b*) The knee-roots of Bruguiera. (*c*) The up-growing roots of Avicennia

above mud level, as though supported by flying buttresses (Fig. 22). In others (Avicennia and Sonneratia), the main roots are horizontal with many small branches exposing themselves through the mud to stand up above its surface in great numbers covering a wide area round the tree. Another mangrove, Bruguiera, has lateral roots which bend in loops showing above the mud; these loops are called knees and make a great obstacle to movement between the trees. These special root adaptations protrude through the mud to reach free air and they have breathing pores (lenticels); their function may be to oxygenate the roots but they also enable fresh rootlets to be put out at higher and higher levels as the mud and silt increases and stifles the older roots. Many mangrove plants have seeds which germinate before leaving the parent tree. Being heavy and fleshy, they can stick firmly in the mud at low tide or may float away in the tidal currents for considerable distances; other germinated seedlings are shaped like darts to pierce deeply into the mud when they fall.

The main differences between mangrove species are the result of selection according to the amount of tidal inundation they can tolerate; the tide is the chief selective factor in the vegetation pattern from place to place in any one mangrove forest and results in a belt zonation of types roughly paralleling the shoreline. The seaward plants, the pioneers, are most tolerant of salt water; the inland fringe is of the least salt-tolerant types and, as the silt is progressively built up, tidal effects diminish and the vegetation gradually turns into a freshwater swamp with different associations.

The nipa palm (Nipa fruticans), with short stem and feathery leaves often 18 ft. long, lines many estuaries where tidal influence is weakening. It is a palm of brackish but not saline preferences and is extensively used for thatching huts.

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(2) Lowland Vegetation

Tropical Rain Forest.—This primary forest is evergreen, tall and profusely-leaved, but by no means gloomy; the forest floor is usually dappled with sunlight at midday and the undergrowth is fairly thin, except at the edges of roads, paths or rivers, where extra

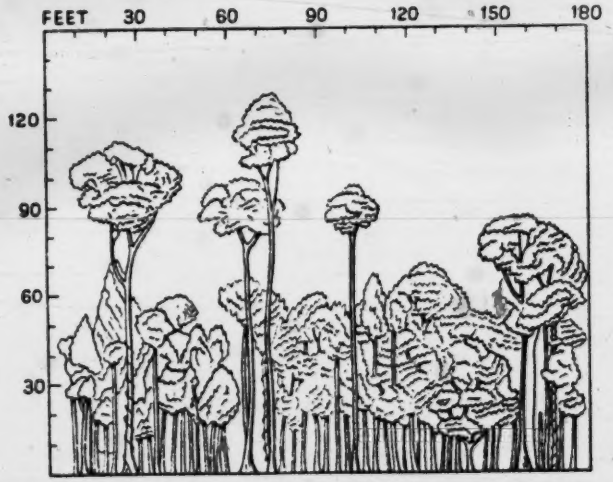

Fig. 23.—Tropical Rain Forest in Profile. The diagram represents a strip of forest 180 ft. in width. Note: (i) the height of the trees; (ii) the crowns are represented in a conventional manner

light induces dense ground vegetation. Within the forest, air is still and constant at temperatures as much as 10° F. below those at the top of the forest. Plants with showy flowers are unusual; variegated and multicoloured foliage is common, while not modifying the general impression of a dark green landscape.

It is the Tropical Rain Forest which most often gets called "jungle." This word, however, has been applied so loosely from district to district, to vegetation types ranging from forest to dry scrub, that it has lost precise meaning and should be avoided.

A distinct structure shows in Tropical Rain Forest, based on height and light. Trees some 190 ft. high are scattered throughout the forest, jutting their isolated heads through a layer of foliage some 60 ft. high, where the crowns of trees touch one another to form a canopy or storey (Fig. 23). Below this are shrubs, saplings and herbaceous plants, all shade-loving types and thinly scattered. On the whole the trees are evergreen, though there are distinct

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137 leaf changes in individual trees. This change of leaves is not regional and some trees retain old leaves until new ones are well formed. The general impression of evergreen persists as a result of a non-synchronous leaf rhythm. The degree of correlation between flowering, leafing and climate varies considerably; certain of the forest plants flower after a few days of drought or a slight local drop of temperature, as in thunderstorms, others persist in annual rhythms whatever the local weather may be, some correlate with the local peaks of rainfall, and some assume a fifteen months' periodicity. Each storey of trees has special features; the topmost storey has thin straight boles despite the great height of the trees, and is inclined to flattened crowns of undivided, tough, oval leaves. Many of the tall trees have plank buttresses, thin outgrowths extending up to 15 ft. from the ground, stabilising the relatively thin boles in soils not well suited for root anchoring, and presenting a major difficulty when the trees are to be felled. Second storey trees are in general smaller in every respect; their leaves are proportionately larger, extending to long fine points.

Two groups of plants fit into this tree ecology: (*a*) the lianes, (*b*) the epiphytes.

Lianes are woody creepers, often several hundred feet long, which climb from the ground using hooks and tendrils on the tree-trunks in order to reach the sunlit crowns. They use trees as supports only and spread in great festoons from tree to tree; their flowers are in the upper storeys and their stems may be from finger thickness to as much as 10 in. in diameter. Rattans are typical lianes, their strong thorny stems being much used as native ropes and wires.

Epiphytes include orchids, ferns and wild figs. Their seeds become established in high branches and are adapted either to live self-contained above ground, or as in the case of the strangling fig (Ficus), to send down very long roots which ultimately fasten in the ground. Only certain of these epiphytes are truly parasitic, feeding on the sap of a host; most of them are merely supported by the host-tree. The fig sends down tough quick-growing roots round the trunk of another tree, finally strangling the host until it rots away, leaving the fig tree sustained by a hollow network of roots. This particular plant, the seeds of which are both bird-carried and wind-borne, may prove highly destructive to stone structures, as in the case of the Angkor temples.

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Tropical Rain Forest is remarkable for the number of tree-types which go to make it and for its heterogeneous composition. Continuous stands of any single tree species very rarely occur, and often thirty may be found in a forest patch 100 yds. square. While the trees differ widely, the family group Dipterocarpaceae, gigantic in dimensions and bearing winged seeds like shuttlecocks, is the most prominent. Within the forest individual trees are restricted by the congestion so that the shape of high trees in tropical gardens or along roads is no guide to their shape when in their natural setting.

From the thousands of tree types in this forest some commercially valuable timbers, gums, resins and camphor can be obtained. Most of the trees, however, are commercially useless; the heterogeneous composition and density of the forest operates against exploitation of even those species which could prove useful.

Within the Tropical Rain Forest, several subsidiary types may be recognised.

(*a*) Parts of Borneo, Sumatra and Malaya have a white, porous, sandy subsoil thought to be a tropical podsol (see Chapter 5). Upon this, pitcher plants, conifers and a treeless, heathlike ecology of grasses and shrubs may develop.

(*b*) Upon porous limestone landscapes, the trees are short and epiphytic plants are most common, since these can tolerate the absence of groundwater.

(*c*) Behind the mangroves and transitional between them and the true lowland Tropical Rain Forest, are Freshwater Swamp Forests, extensively developed in Sumatra, Malaya and Borneo. The plants peculiar to this swamp setting vary with the duration of freshwater flooding. Trees here are shorter, fewer in species, well-buttressed and often stilt-rooted. Over considerable areas stands of a single type of palm may occur and palms of short varieties cover the ground to impede movement. Sometimes on the east coast of Sumatra the Freshwater Swamp Forest produces a tropical bog on peat soil formed by rotting vegetal remains several yards deep.

Secondary Forest.—The sequence of vegetation which replaces Tropical Rain Forest after removal is called Secondary Forest, made up of ferns, tropical grasses and scrub. It may be subdivided into distinct vegetation types which are various stages in the transition from naked ground to tropical forest. The process of replace-

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137 ment depends for its character in detail on the length of time the forest clearing has continued in cultivation, the extent of soil erosion, the clearing suffered, the original soil type and the proximity of natural forest from which seeds may be derived. To go through these replacement phases, natural vegetation is thought to need at least two centuries of most favourable conditions before it will become anything like Primary Tropical Rain Forest again. During the transitional stages spontaneous fires often occur, to prolong the replacement period; grazing animals have similar selective effects.

The normal replacement succession is first herbaceous grassland, then shrubs and finally trees. Tropical grasses, coarse, tough and in tussocks, quickly appear on any newly exposed ground and reach a height of 5 ft. These grass landscapes, on which Imperata Cylindrica is typical, often resemble savannah. The grass burns rapidly and regrows quickly because it spreads by subsurface root runners shielded from the effects of burning. Quick-growing tropical grass stifles most other vegetation, so that it is both a sign of inferior soils and may even be the cause of them. While grass is the most prominent type, sometimes wild sugar canes establish themselves.

The scrub consists of wild ginger and a tropical rhododendron (Melastoma malabathricum). Giant ferns spread rapidly and compactly in some districts as pure stands in which bracken (Pteridium) appears prominently.

Young Secondary Forest develops trees some 30 ft. high in a few years but the earlier successions leave behind a dense undergrowth and many giant creepers. Stands of the same species persist for some time and the trees are at first of fast growing, soft wooded varieties. Pines are fairly common in some local secondary vegetation, the older types of which are scarcely distinguishable from Primary Forest except for the thick undergrowth.

Monsoon Forest.—Because Monsoon Forest has a distinct dry season, it is subject to widespread and frequent fires which exercise a selection in favour of deep-rooted or thick-seeded types which can regrow after a forest fire. Shifting cultivation is thought to have had a greater effect in Monsoon Forest areas than on the Tropical Rain Forest, so that Monsoon Forest may be largely a secondary rather than a primary forest type. The type stretches across Southeast Asia in two broad zones, roughly symmetrical to the Equator. The

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argest zone covers Burma, Siam and Indochina, while the counterpart in Eastern Java, the Sunda Islands and New Guinea covers a much smaller area, with local variants due to insularity. These zones are identical with the dry areas of Fig. 10.

In the rainy season, Monsoon Forest resembles Tropical Rain Forest. Its tree heights are less, the foliage not so profuse, and the spacing more open. Only the undergrowth remains fairly green for the whole year; the rest of the vegetation sheds leaves in the dry season, when the forest has a bare, stark appearance. Herbaceous plants, lianes and bamboo are common but epiphytes are unusual and the herbs almost disappear in the very hot dry season. Among the trees, Acacias and Albizzias are especially common and Leguminosae are prominent.

Some observers distinguish between wetter and drier types of Monsoon Forest, both transitional from Tropical Rain Forest to Tropical Desert, the latter being outside Southeast Asia.

Monsoon Forest is mostly of mixed species but sometimes a single species dominates, possibly as a result of selection through repeated burning. Of these, teak forests (Tectona grandis) are characteristic and important commercially, occurring in Northern Burma, Northern Siam, Eastern Java and the Moluccas. So valuable has teak proved itself that some existing forest areas are actually re-plantations of it. Teak has thick hard-cased seeds which are fire resistant. Its saplings come through fire successfully and the pure stands are thought to have been the result of natural selection on these lines, since it is fairly certain that forests of teak alone do not occur under natural conditions. Teak reaches to heights of over 120 ft., the lower half of the tree being straight and unbranched under forest conditions. Undergrowth is negligible and the ground is covered with brittle teak leaves which often cup, forming mosquito-breeding places in the wet season.

Resembling the teak forests in origin, eucalyptus forests have developed in the eastern islands as migrants from Australia, occurring naturally only in New Guinea, Timor, the Lesser Sundas, Celebes and the Philippines.

Another single stand deriving from the Monsoon Forest by selection, is bamboo forest. Considerable areas almost exclusively occupied by bamboos are found in the northern parts of Southeast Asia, with small patches in East Java. Bamboos in great variety grow everywhere in Southeast Asia and they have been planted

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extensively because of their usefulness structurally and domestically, but continuous stands become established only where the dry season is very marked and where shifting cultivation is known to have been practised extensively. Bamboos are giant perennial grasses of about a hundred species, with woody stems and woody roots. They grow in clumps and may be evergreen or deciduous. Some bamboos flower at long intervals (25-70 years) and their seeds are fire-resisting. Constant friction between the dry woody stems may cause forest fires and help to produce that selective process which leads to stands of bamboo.

Monsoon Dry Forest, an open wooded landscape containing very few species, may be found over large areas of Burma, Siam and Indochina in association with poor soils. Known as *indaing* in Burma and *padeng* in Siam, this forest develops where rainfalls are not much above 40 in. per annum, and it may merge on the equatorial side into Tropical Rain Forest and on the other into dry or thorny savannah vegetation. Within Monsoon Dry Forest trees are widely spaced, tending to be stunted forms of Dipterocarpaceae and distinctly deciduous.

Secondary Monsoon Forests.—Considerable areas of savannah found in Burma, Siam, Indochina and the Eastern Indies are secondary growths after a removal of the natural Monsoon Forest. Savannah is open country of tall, coarse grasses, occasionally having a few scattered bamboos or low trees and very much associated with long dry seasons whose effects are aggravated by poor or porous soils. Savannah merges into Monsoon Dry Forest and is often covered with low palms (Borassus flabellifer), and contains prickly pears, spiny cactus-like plants, and similar thorny scrub.

(3) Mountain Vegetation

Vegetation steadily and often imperceptibly changes with altitude and the resulting types are much the same, level for level, throughout Southeast Asia. All but the very highest mountains are forested, though the trees on exposed summits are dwarfed; only in New Guinea and Yunnan are the heights great enough entirely to prevent tree growth and produce an alpine vegetation. Young volcanoes may be treeless for pedological, rather than for climatic reasons.

Above about 2,000 ft., at most points of Southeast Asia, large

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trees of Dipterocarp type gradually disappear and temperate trees of the oak and chestnut type become commoner, though the landscape continues full of giant bracken and tree ferns. Higher still the vegetation dwarfs considerably, shadiness diminishes, and woody plants become twisted and gnarled. This often turns into a moss or "elfin" forest above 5,000 ft., in localities where the air is constantly cool and saturated, to produce thick blankets of wet mosses and liverworts upon all other vegetation. Mosses hang in fantastic festoons everywhere and sometimes (as in Borneo) form walls or platforms under which other vegetation, such as dwarf oaks and rhododendrons, are buried (Harrison). Moss forest will not occur in localities with a noticeable dry season: in monsoon areas it is replaced in succession by pine forest, in which, however, some broadleaved trees persist. Above both these mountain forest types (above 6,500 ft.), mountain grasses and shrubs form landscapes of rolling downlike appearance.

Fauna

Between the western and eastern fringes of Southeast Asia there are greater differences zoologically than between Asia and South America, even though these are separated by the Atlantic (Merrill). The differences derive from the long separation of Australia from Asia. Migration has gone on from Asia and Australia into the islands and peninsulas of Southeast Asia which is thus a transitional zoogeographical region (Fig. 24).

The Tropical Rain Forest has complicated ecologies of living creatures associated with the various storeys and the variety of these creatures parallels the variety of vegetation. Large animals such as elephants, tigers, rhinoceros, etc., are relatively few and confined to the coastal sections. Specially numerous are arboreal and flying creatures, butterflies, birds, moths and insects. These are able to migrate from place to place with considerable ease so that the convergence of Asiatic and Australian species has gone on fairly freely. The contrasting zoological types are summed up in the difference between mammals; in Australia, except for a few bats and rodents, mammals are marsupial (pouched) or monotreme (single vented); in Asia these groups are entirely lacking and are replaced by placental mammals, monkeys, shrews, squirrels and ungulates.

By far the richest zoological group is that spreading from Asia.

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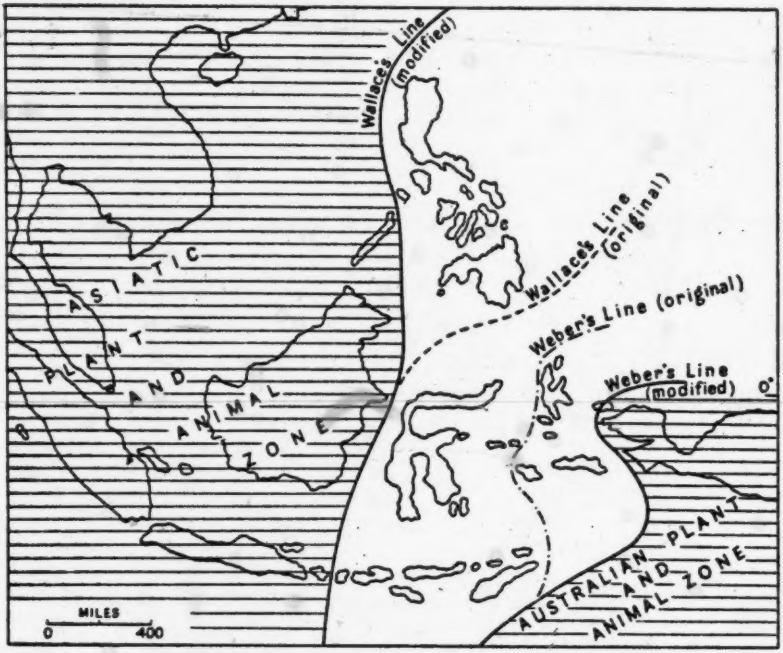

FIG. 24.—Biological Regions of Southeast Asia

136 For a long time Wallace's Line was held to demarcate these zoological types; Wallace himself drew the boundary just west of Lombok and Celebes but Huxley later extended it to include the Philippines in the "Australian" zone. Geographically the boundary clearly correlates with the limits of the Sunda Platform and the interglacial connection between Malaya, Borneo, Sumatra and Java appears to have permitted zoological migration fairly uniformly among them, whereas there has been no continued land connection between the "mediterranean islands" east of the Platform. Later more detailed study of the fauna has produced criticisms of the Wallace Line. The steady pressure of zoological types eastward has been demonstrated and Weber laid down another limit which he showed more closely to accord with the balance between Asiatic and Australian fauna. East of it Australian types dominate. Wallace's Line thus is now best thought of as the eastward limit of the typically Asiatic zoological types; it is matched by a line just west of the Sahul Shelf which is the westward limit of exclusively Australian and New Guinea faunal types.